Thermally-stranded high pour point oils in the Uinta Basin, Utah

Steven Schamel
GeoX Consulting Inc
Salt Lake City, Utah
geox-slc@comcast.net

Introduction

Thermally-stranded oils are those found in reservoirs that are colder than the pour point of the oil. Thus, they are immobile because they are "frozen", not due to high viscosity.

The paraffinic oil sourced from the Green River Formation in the Uinta Basin has pour point in the 80º to 115ºF (27º - 46ºC) range.

Shallow, thermally-stranded oil has been reported informally, without documentation, from most parts of the basin.

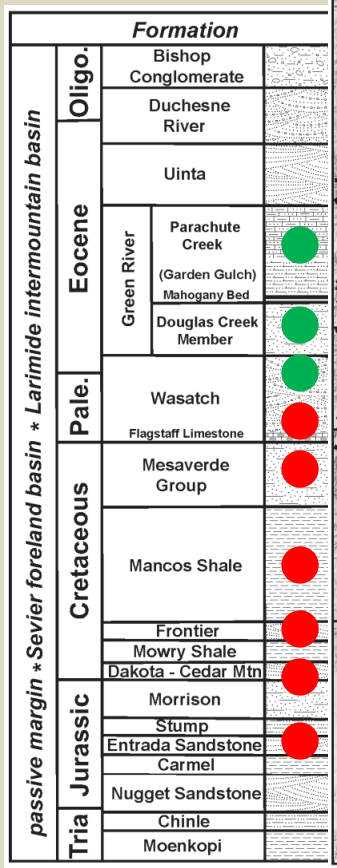
In the quest to develop the larger conventional oil resources of the basin, this type of oil accumulation has been overlooked. Yet it may constitute a substantial oil resource that is economically recoverable by *in situ* thermal recovery methods.

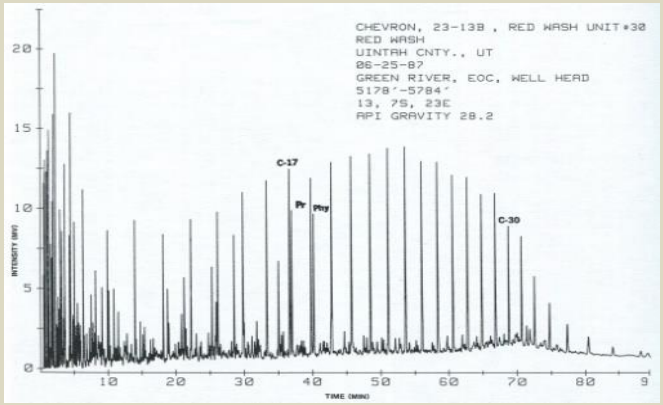
1. Conventional deep oil & gas

Uinta Basin has produced half of Utah's total oil and gas: 705 MMBO + 5.38 Tcf gas

Oil is sourced from the organic-rich lacustrine Green River Formation and produced from sandstone and bioclastic limestone reservoirs in the formation and underlying Wasatch Formation.

Gas is from Cretaceous gas-prone source rocks and sandstone reservoirs.





Green River-sourced oil

API gravity: 27º to 45º

Pour point: 80º to 115ºF (27º - 46ºC)

BHT: 140º to 220ºF (60º - 104ºC)

API and BHT generally increase with depth

2. Shallow bitumen & heavy oils

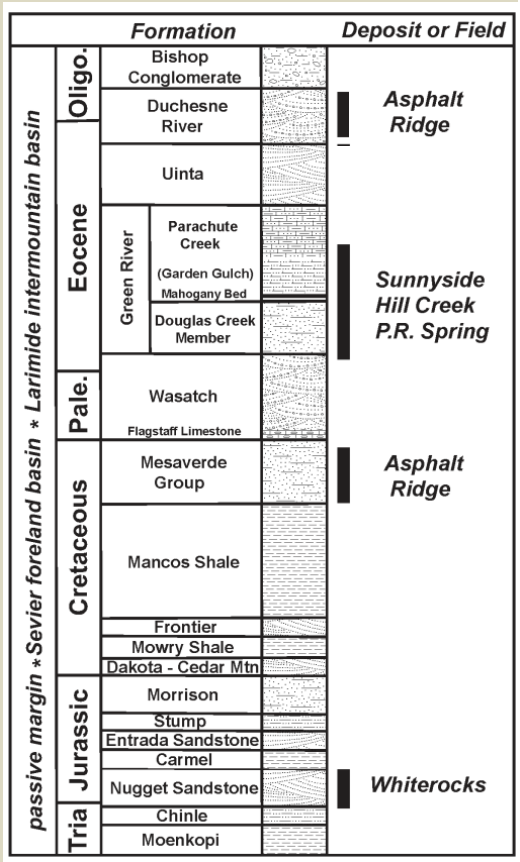
Over 10 billion barrels of bitumen and heavy oil in shallow accumulations on the elevated margins of the basin.

Biodegraded normal oil.

Stratigraphic traps on the south flank similar to those in the deep basin center.

Structural traps in older sandstone units on the north flank.

Historically, the bitumen mined for road construction, but no commercial extraction of fossil fuel from the deposits.



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3. Shallow thermally-stranded oil

Oil is normal high-wax crude or very little altered by biodegradation.

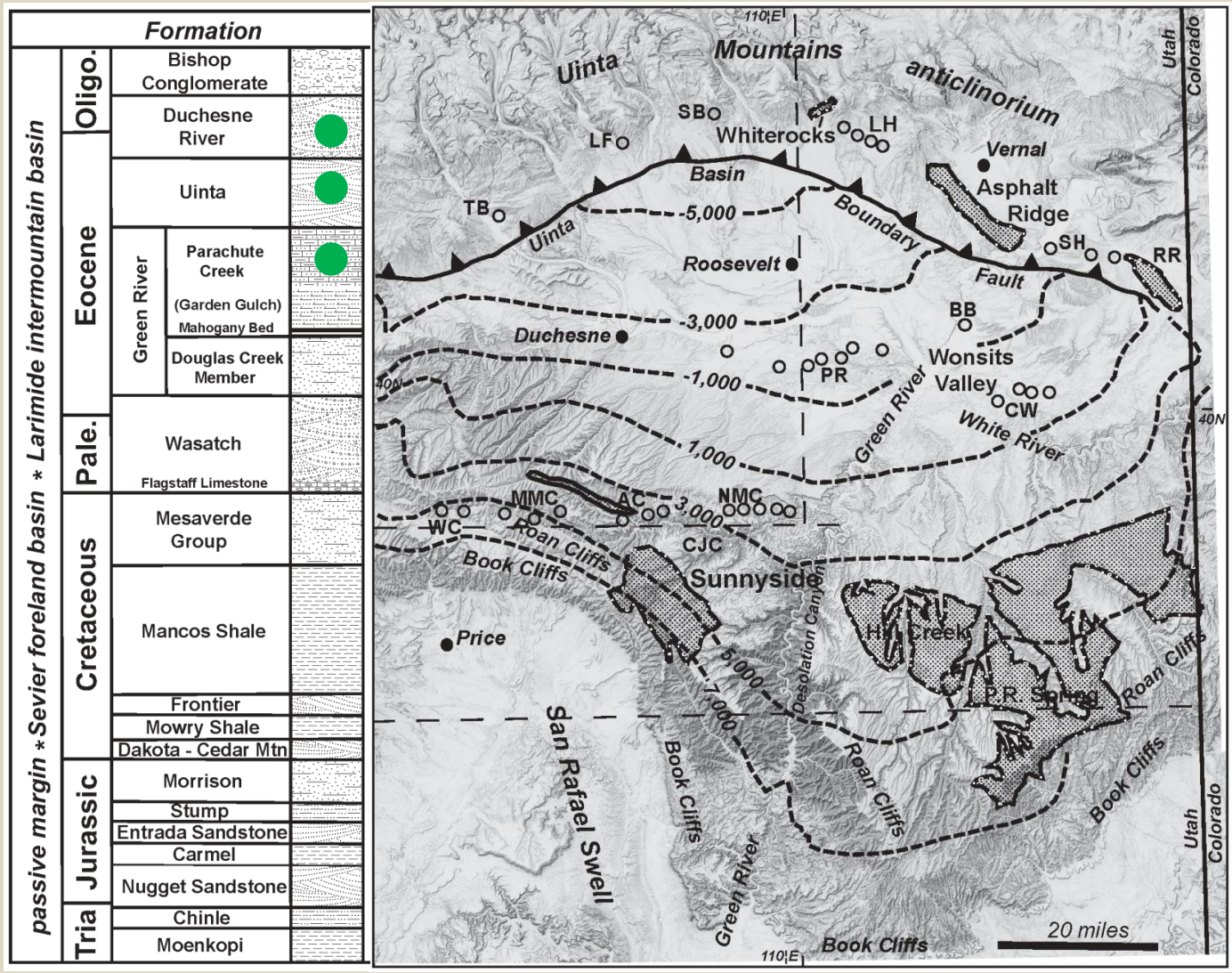
In reservoirs less than a few thousand of feet deep. Overlie the conventional oil fields in basin center.

Reservoir temperature less than pour point of the oil.

Commonly shallower than the initial casing string and start of wireline logging.

Wonsits Valley field has been documented.

An intermediate setting between the deep oil pools and the shallow bitumen accumulations.



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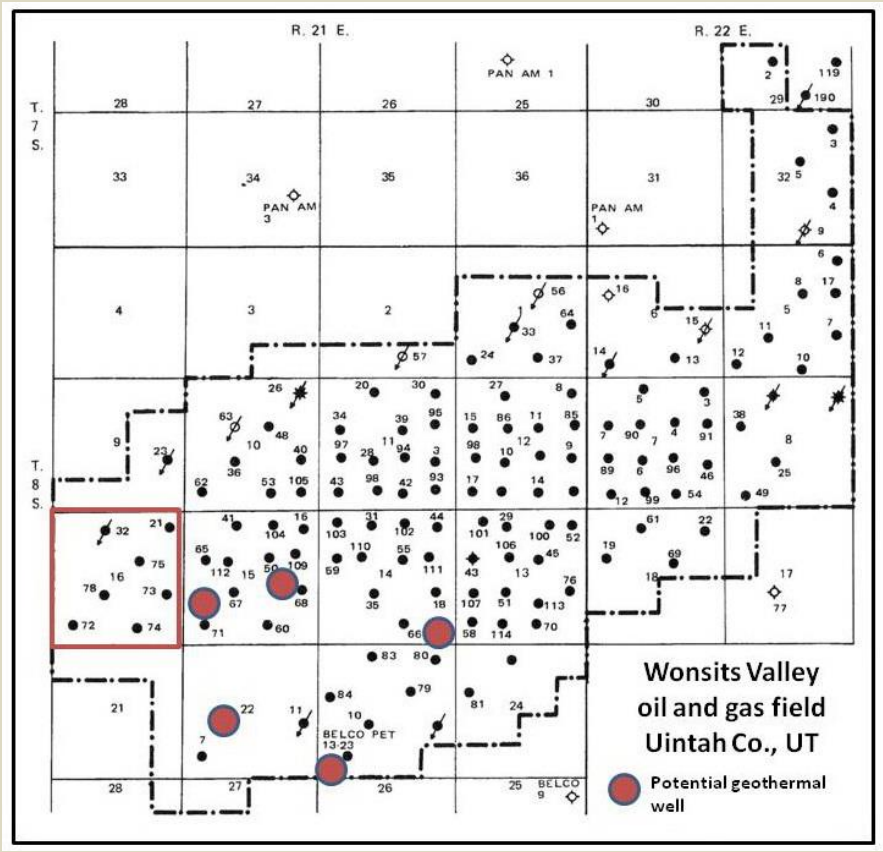
Wonsits Valley field

Located in the southeast Uinta Basin immediately northeast of the confluence of the Green and White Rivers. The field merges into adjacent Red Wash and Gypsum Hills. Initially, production in all fields was from sandstone lenses in the upper Green River Formation.

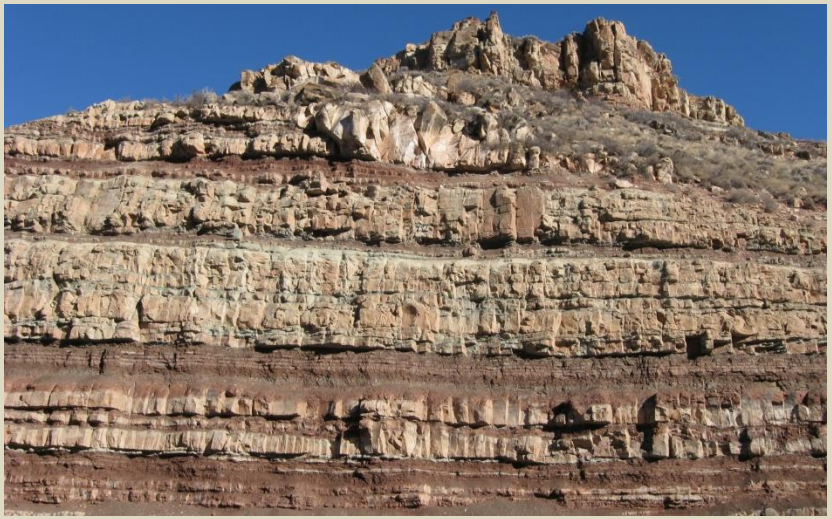
The field was discovered by Gulf Oil in 1962 and over the next decade developed on 40-acre spacing. In 1971 the wire-line longs from these initial wells was used to evaluate the shallow immobile oil in the Uinta Formation.

In 1978 three test wells were drilled in Section 16 to further characterize the reservoir sandstones and thermally-stranded oil. An internal report was prepared by Chevron in 1981.

When Chevron sold the field in the 1990s, the reports were given to the Utah Geological Survey.



Uinta Formation



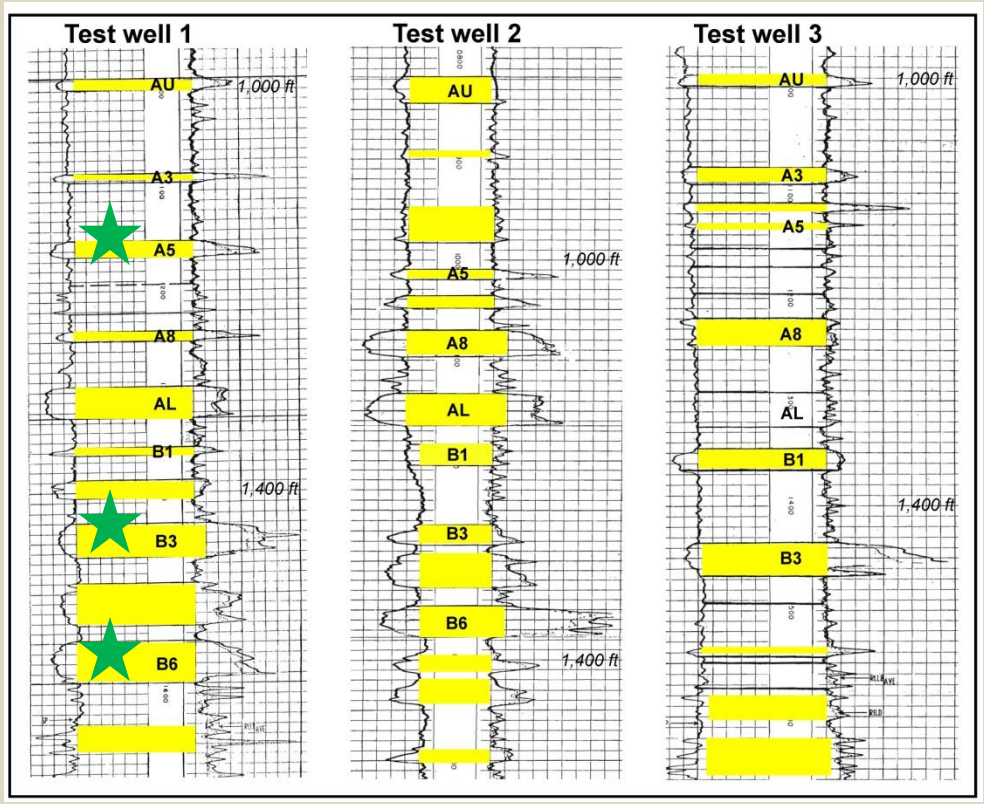
A fluvial mudstone succession with an array of channel sandstones.

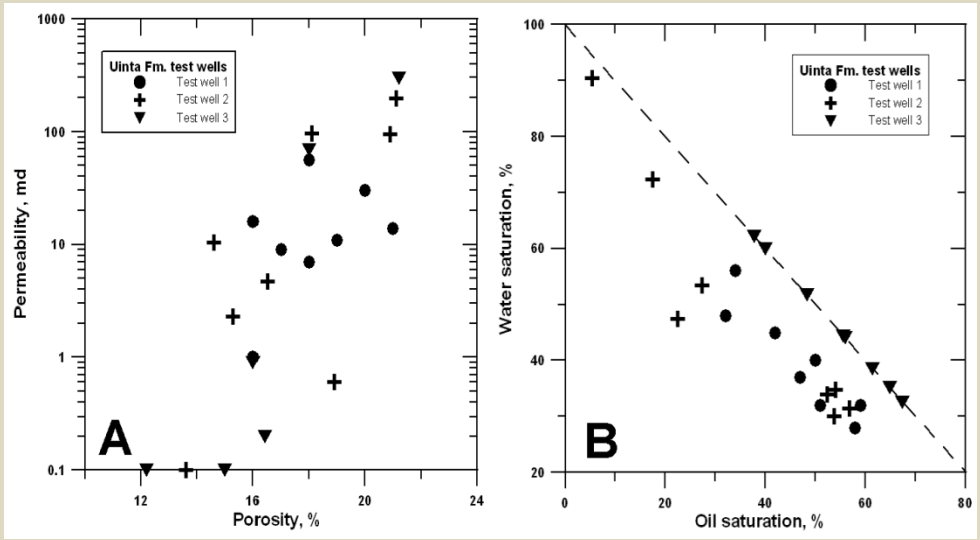
The sands are fine grained with high silt and clay content.

Average porosity ranges from 16.5% to 18.1 %. Permeability ranges widely, but the averages are 18 md to 61 md.

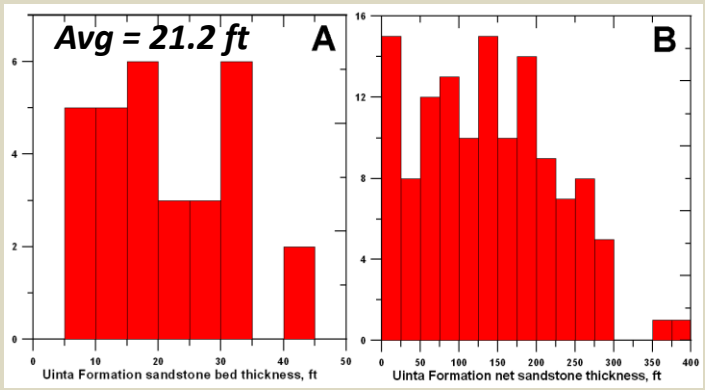
These are reservoirs of marginal quality.

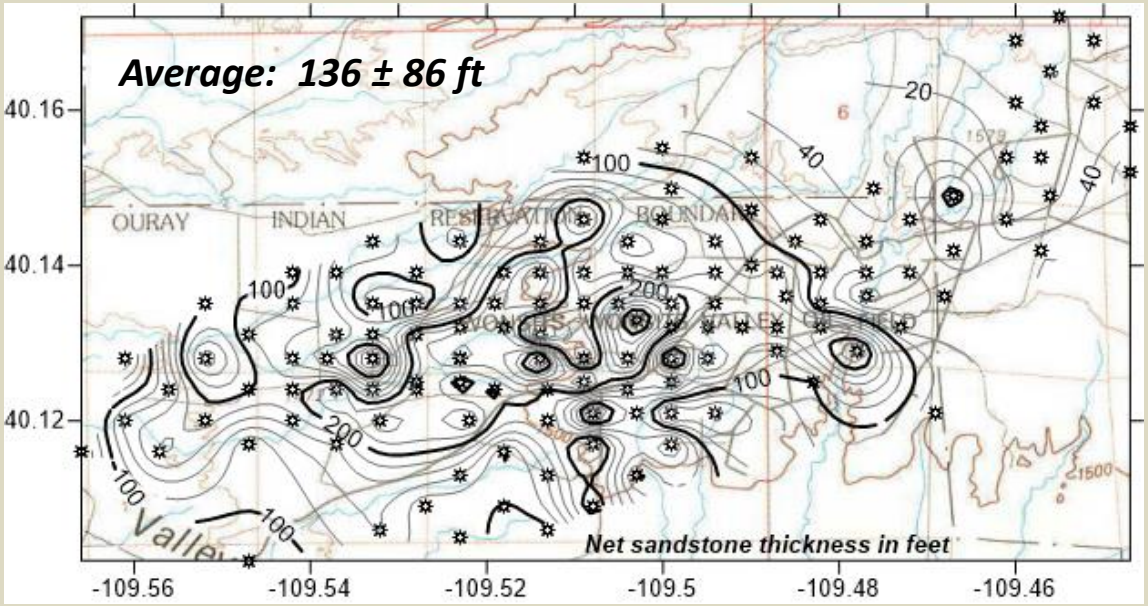
★ *Oil sample*





Reservoir net thickness and estimated oil resource

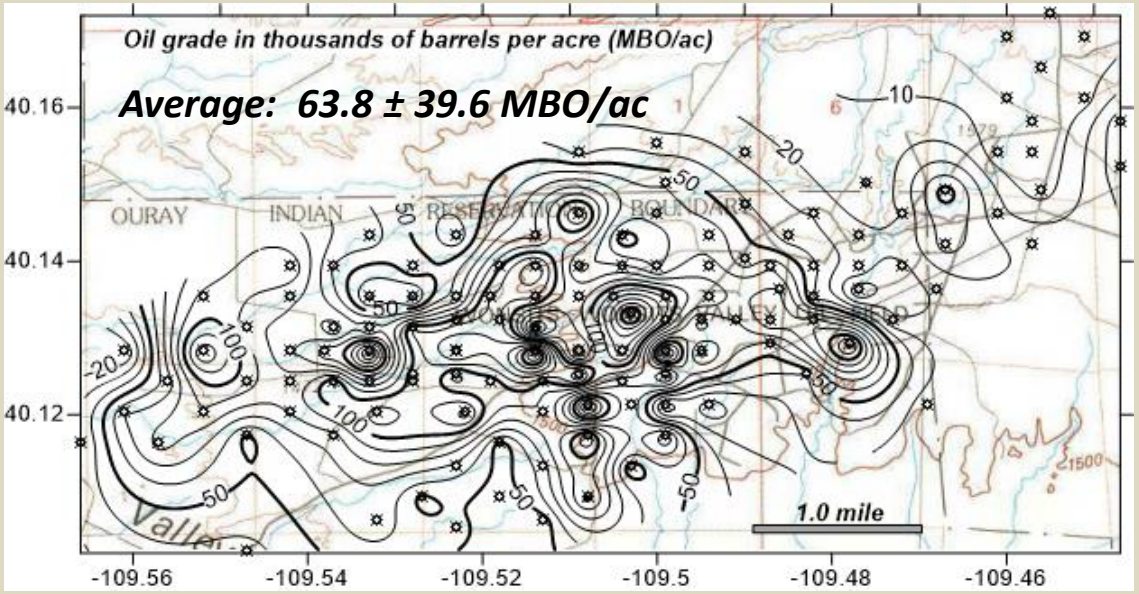




The original oil-in-place is calculated from the net sandstone thickness x oil grade of 470 barrels per acre-foot, as determined from cores.

Approximately 4,420 acres (6.9 mi^2) have OOIP greater than 50 MBO/ac resulting in a resource estimate of <u>310 MMBO</u>.

This is a conservative estimate.



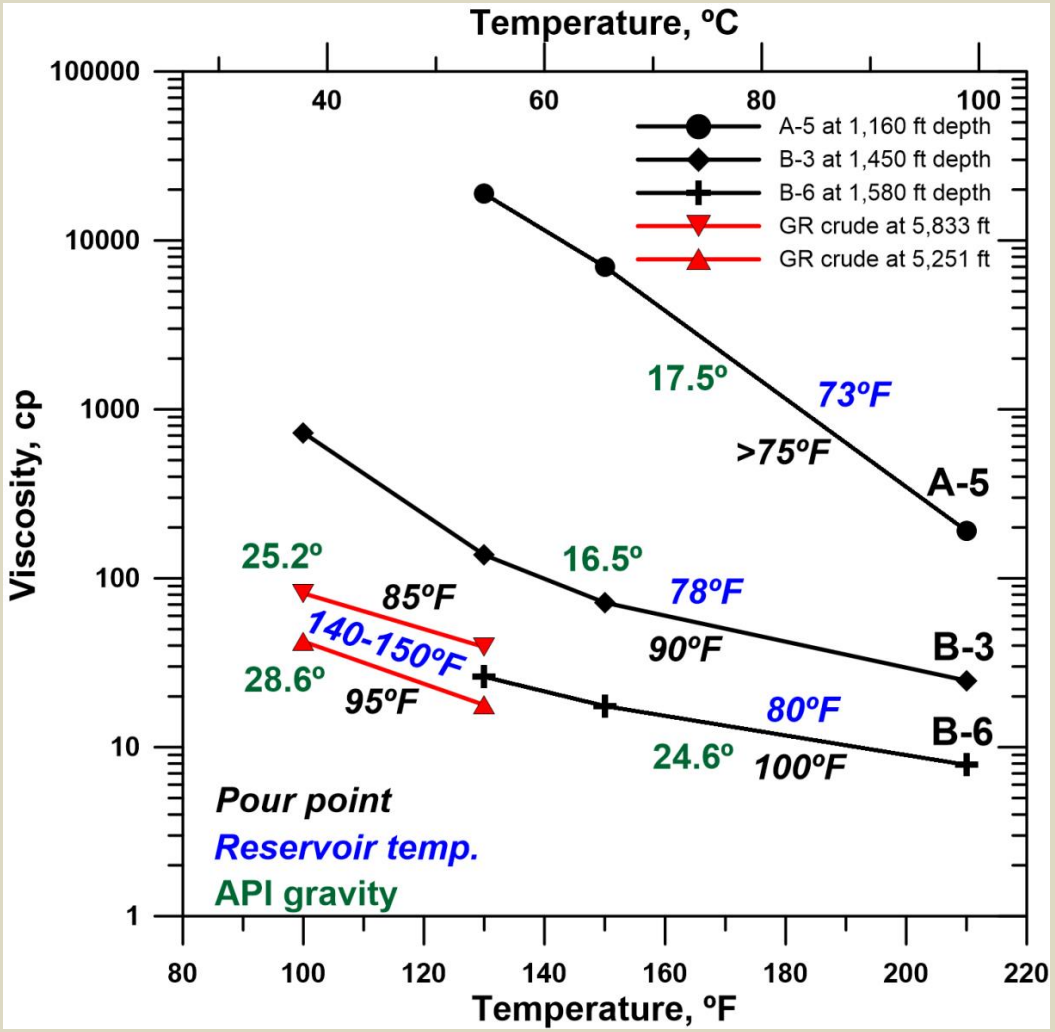
Wonsits Valley oil properties

Three oil samples were taken from test well 1. Sample depths are 1160 ft, 1450 ft, and 1580 ft.

All oil properties vary with depths indicating degrees of biodegredation of the shallower oils.

All three oils have pour points higher than the reservoir temperature.

The viscosity of the deepest oil (B-6) is essentially identical to oils in the Wonsets Valley field from Green River reservoirs below 5000 ft depth.



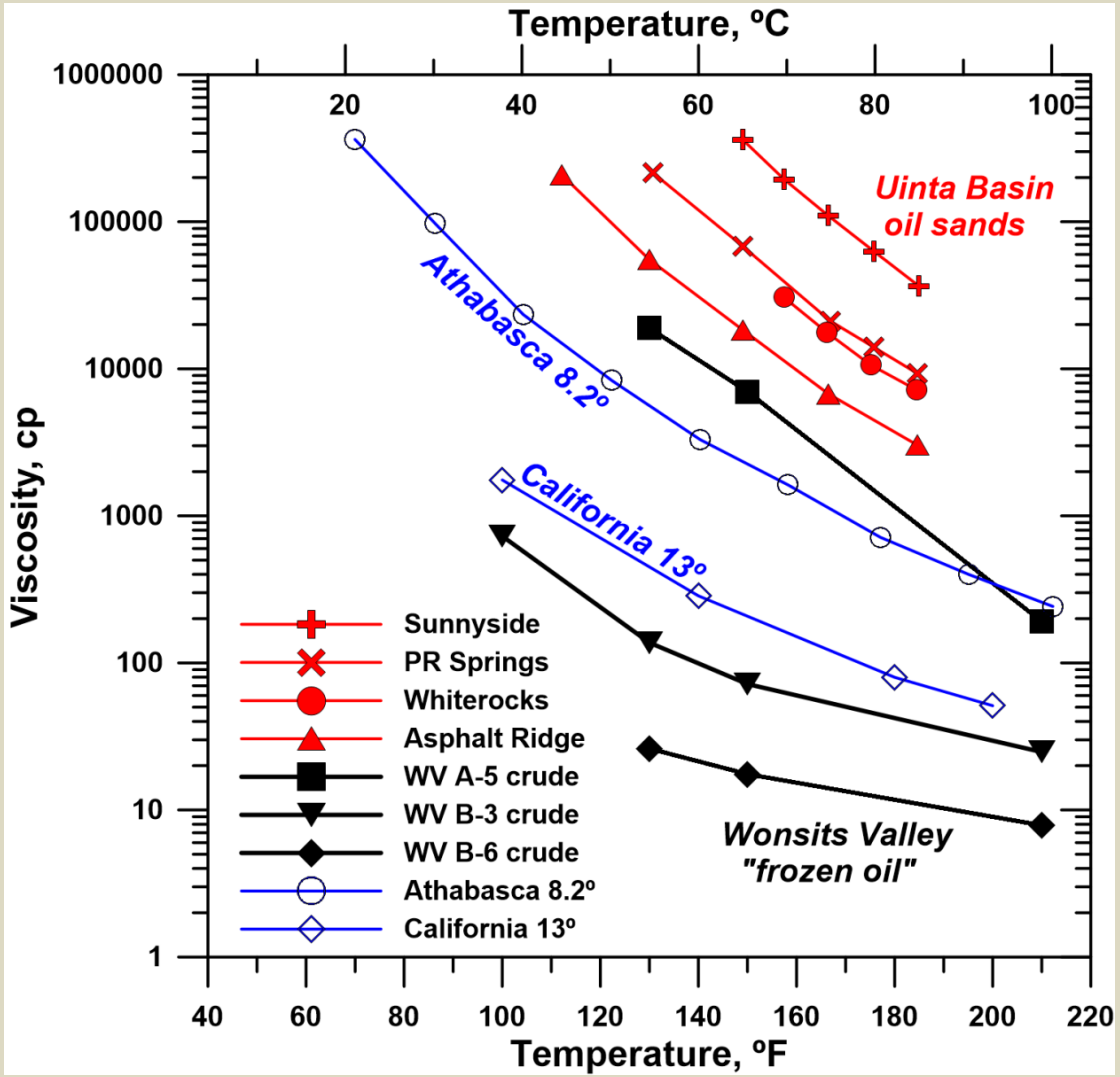
	A-5 crude	B-3 crude	B-6 crude
Depth, ft	1,160	1,450	1,580
API gravity	17.5	16.5	24.6
Wax content, wt %	14.7	17.6	33.2
Asphaltene, wt %	15.0	8.2	4.1
Sulfur, wt %	0.24	0.27	0.30
Heating value, BTU/lb	18,491	18,489	19,346

Wonsits Valley oil viscosity

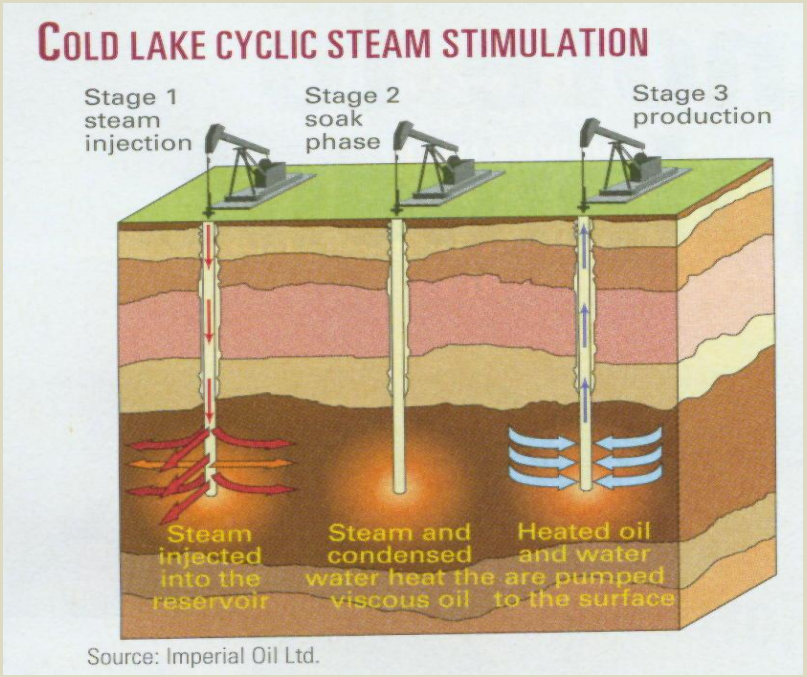
The two deeper oils, at 1450 and 1580 ft have viscosity profiles comparable to the normal Green River high-wax oil.

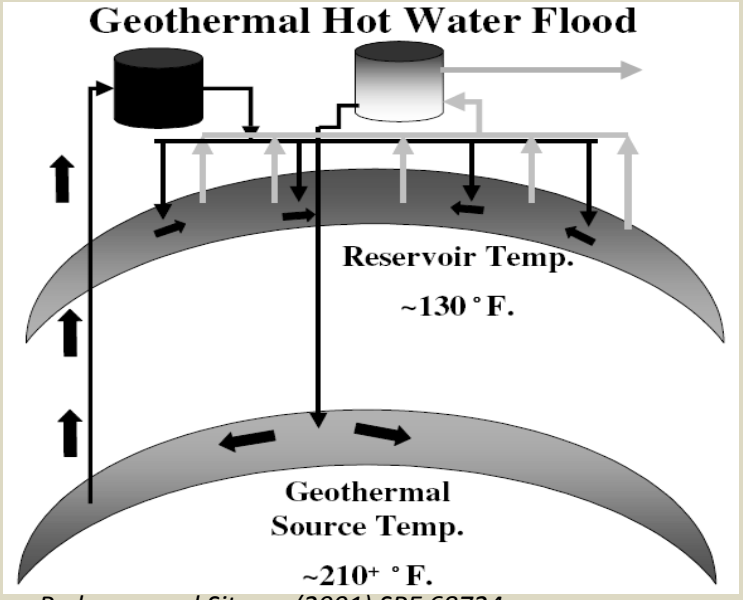
A relatively small temperature increase less than 100º F should be sufficient to liberate the oil from the Uinta sandstone reservoir.

The initial drive mechanism may be solution gas, as with the deep Green River reservoired oils.



Options for thermal *in situ* oil recovery

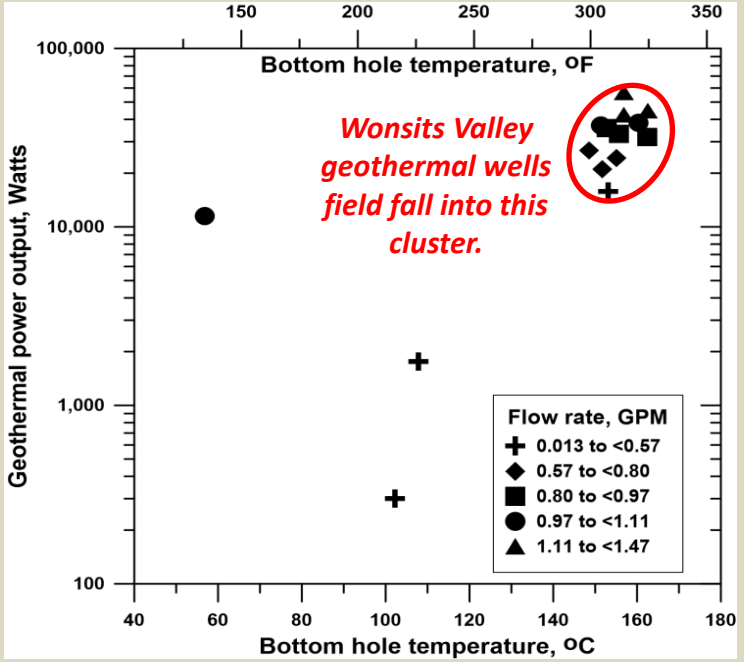




Pederson and Sitorus (2001) SPE 68724

Geothermal power potentially available ?

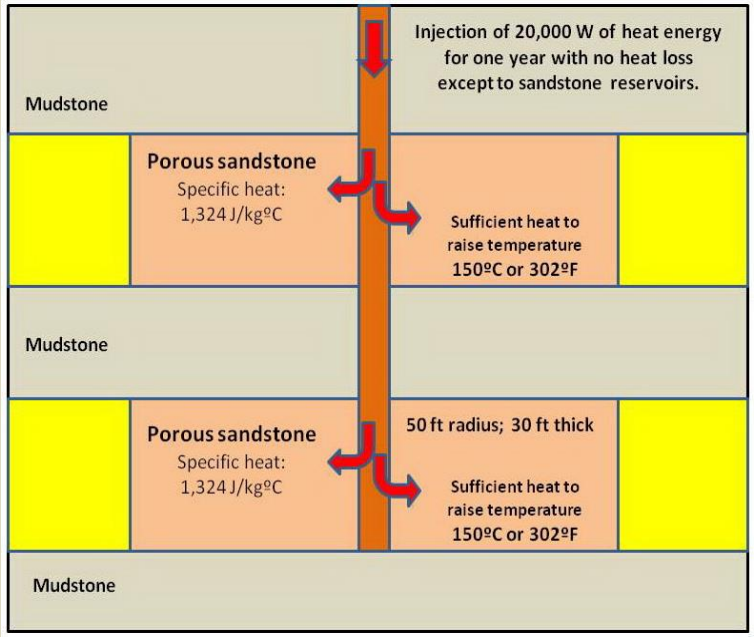
Well Name	Depth, m	BHT,°C	Grad,°C/km	BW/year	GPM	Q/sec, Watt
OURAY 34-79	4,927	153.1	31.1	5,281	0.422	15,778
WVX 11D-22-8-21	5,099	162.6	31.9	14,034	1.121	44,752
GB 4D-28-8-21	4,617	148.5	32.2	9,272	0.741	26,799
GB 16D-28-8-21	5,002	162.4	32.5	10,000	0.799	31,846
GB 1D-27-8-21	4,917	155.1	31.5	8,013	0.640	24,279
GH 7D-19-8-21	5,221	156.9	30.1	18,436	1.473	56,564
GH 6-20-8-21	5,202	156.8	30.1	13,873	1.109	42,535
WV 16C-14-8-21	5,086	151.4	29.8	12,523	1.001	36,964
WV 8D-15-8-21	5,172	155.7	30.1	10,920	0.873	33,226
WV 13D-23-8-21	5,011	160.3	32	12,172	0.973	38,222
WV 13A-15-8-21	5,176	152.7	29.5	12,009	0.960	35,777
WV 11AD-14-8-21	5,143	151.7	29.5	7,102	0.568	21,008
GB 11M-27-8-21	3,737	107.8	28.8	867	0.069	1,759
FEDERAL 33-92	2,759	102.2	37	157	0.013	300
GHX 13HG-17-8-21	2,601	56.8	21.8	12,107	0.967	11,485



Geothermal power is calculated using the average flow rate (GPM) of produced water over the past 12 months and the BHT less an average surface temperature of 12ºC.

Just half of that quantity of heat energy (20,000 W), if injected over the course of one year, could raise the temperature of two reservoir beds of dimensions shown in figure to the right 150ºC or 270ºF, assuming all geothermal power could be delivered to the reservoir units.

BHT and gradient data from Hardwick and others (2015)



Formation water salinity an issue?

Are the hot produced formation waters too saline to inject directly into Uinta Formation reservoirs?

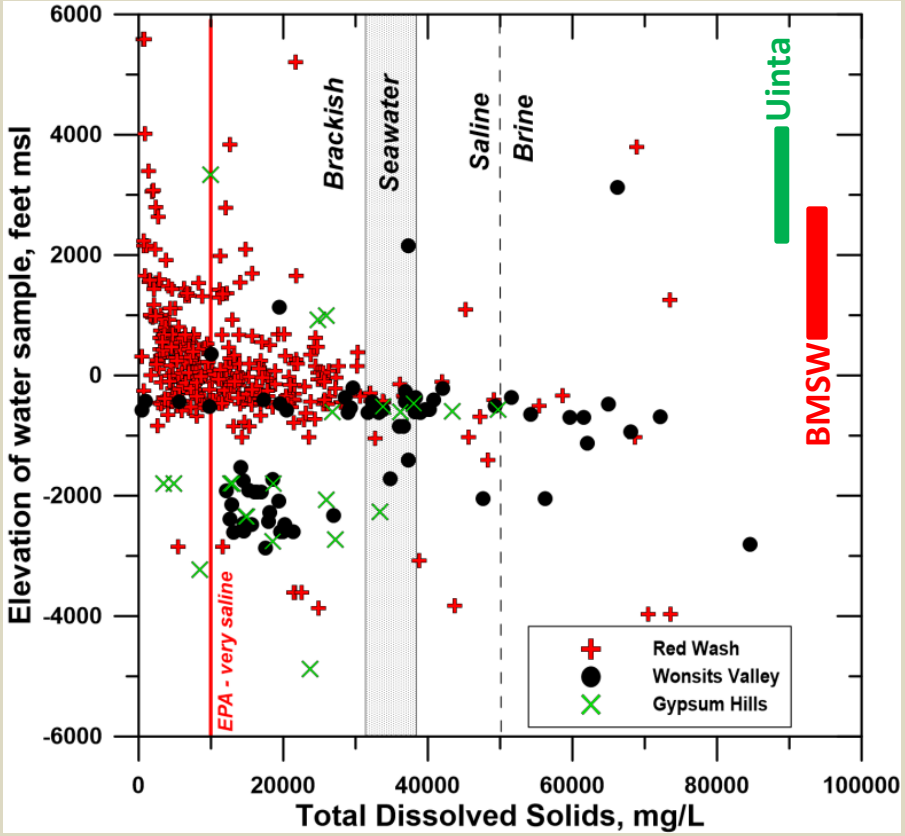
Produced water cannot be injected into strata with lower TDS concentration.

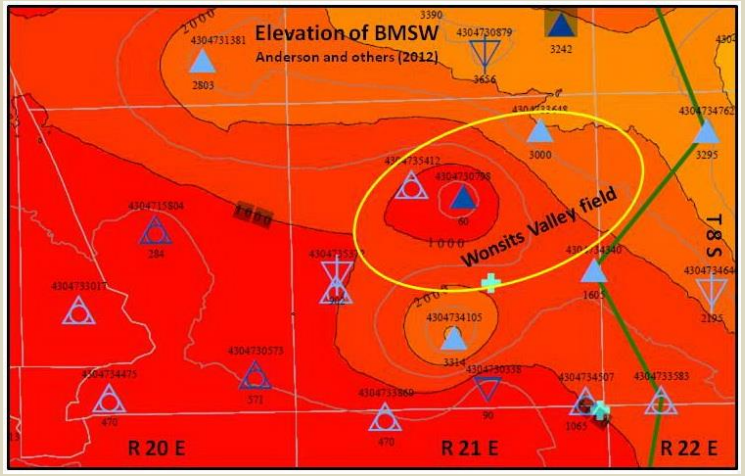
EPA guidelines call for no formation water disposal above the “base of moderately saline water” (BMSW) defined as TDS of 1000 mg/L.

Across the Wonsits Valley field the BMSW dips southwest from about 3000 ft msl to below 1000 ft msl.

This surface generally is <u>below</u> the elevation of the Uinta Formation within the field. Produced water cannot be reinjected.

Data from Anderson and others (2012)





Conclusions

The thermally-stranded high pour point oil in the Wonsits Valley field provides a glimpse of the potential of this long-neglected oil resource and the technical challenges for its exploitation.

This type of oil accumulation may be widespread across the Uinta Basin and constitute a significant undeveloped resource. This requires that operators in the basin look for it. If found, the resource must be fully evaluated.

If geothermal hot water technology is to be adopted for recovery of the shallow "frozen" oil, that must be done in conjunction with development of the deep oil and gas in the basin. This is the least expensive source of hot water.

Should hot water injection prove untenable, an alternative strategy could be radio frequency heating with solvent injection. This approach holds promise, but it is not yet adequately field tested.